RESEARCH DEPARTMENT

VISIBILITY OF RANDOM NOISE IN A TELEVISION PICTURE

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M. Gilbert, Ph.D., B.Sc., D.I.C.

(W. Proctor Wilson)

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SUMMARY

This report describes an investigation into the relative visibility of narrow bands of noise within a 3 Mc/s video bandwidth. This is an essential preliminary to the assessment of the relative annoyance of different types of noise spectra on the television picture. A set of curves has been deduced and a suitable network has been proposed.

1. INTRODUCTION.

One of the factors which will determine the quality of a picture transmitted over a television system and influence its acceptability is the signal-to-noise ratio. For a given signal-to-noise ratio, however, some types of noise may be more visible or more annoying than other types. The Post Office Engineering Department* have already investigated the relative visibility of three narrow frequency bands of noise taken from a random-noise generator, the three bands having mid-frequencies of 0·15 Mc/s, 1·66 Mc/s and 2·85 Mc/s.

It was decided initially to investigate the relative visibility of a number of narrow frequency bands of noise in the frequency range of 0 to 3·0 Mc/s, and to compare the results with the Post Office investigation. The ultimate aim of the investigation is to provide, if possible, a weighting network which will take into account the variation of visibility of different noise spectra and thus permit of direct objective measurement in terms of annoyance.

It should be pointed out that in these experiments, noise was added to the picture signal only, and had no influence on the synchronising waveform. It is hoped that it will be possible to continue the investigation later, by conducting experiments with noise of different spectral characteristics, such as noise with a triangular spectrum. Such further generalization should be of interest with reference to the quality of pictures originating from specific camera tubes, some of which give rise to noise spectra which are of triangular form.

*G.P.O. Radio Report No. 2020

2. EQUIPMENT.

A noise-generator was designed to operate in the following manner:

The noise voltage appearing across the terminals of a 100,000 ohm resistor (Fig. 1) was fed to the input of a high-gain amplifier having a uniform response to frequencies between 0 and 500 kc/s. The output of the amplifier was used to modulate a 10 Mc/s carrier and the middle region of the resulting upper sideband was selected by a confluent band-pass filter with a pass-band of 10·1 to 10·4 Mc/s.

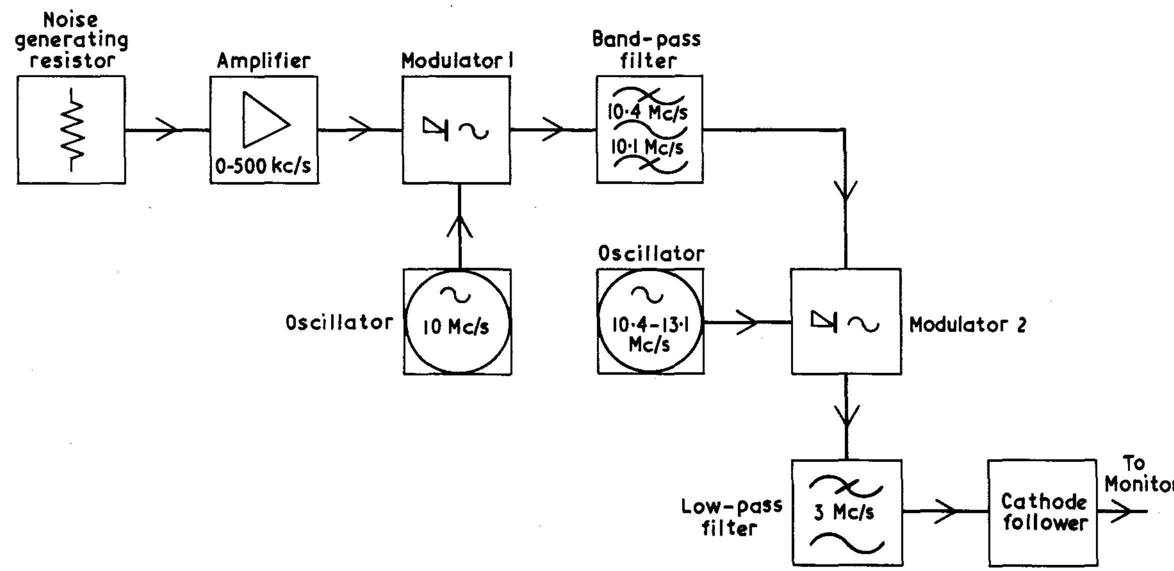

Fig. 1 - Block diagram of random noise generator

A balanced modulator multiplied this signal by the output of an oscillator of frequency variable from 10·4 to 13·1 Mc/s, thereby producing two bands of random noise, both 300 kc/s wide, the mid-frequencies of which were variable from 0·15 to 2·85 Mc/s and 20·65 to 23·35 Mc/s, respectively. A 3 Mc/s low-pass filter removed the upper band of noise, and the lower band was injected into a television camera channel, which, by itself, produced a substantially noise-free signal. It was thus possible to display narrow-band noise spectra, the mid-frequency of which could be continuously varied between 0·15 and 2·85 Mc/s. An attenuator between the apparatus described and the television channel enabled the noise level to be precisely controlled.

This method ensured that the interfering signal contained only random noise frequencies within the limits of the pre-selected "window", but the validity of the results obtained by the method is in some doubt. There is no *a priori* reason for assuming that the annoyance value of a broad band of noise will be the same as the sum of the annoyance values of a number of smaller bands occupying the same total band-width. When a single narrow band of noise is added to a television picture,

areas of "pattern" are observed, and these are not a feature of broad band noise; this effect may be due to the increased probability of correlation between signals displayed on adjacent lines, due to bandwidth restriction. These effects are to be investigated in a later phase of the experiment.

3. PROCEDURE.

Fifteen subjects took part in these preliminary experiments on the visibility of noise in television pictures. It was found convenient to seat five subjects at a time in front of the experimental television screen. Some subjects were, therefore, a little further from the screen than others, but the average distance was approximately four times picture height for one series of observations and eight times picture height for a second series of similar observations.

Each subject was handed a sheet of paper which was divided into four columns headed "Not Visible", "Just Visible", "Just Annoying" and "Very Annoying". It was explained to the subjects that the still picture of the University of London Senate House building, which they could see on the screen, was substantially noise-free, but various amounts and types of noise would be added to it. When an example of random noise with a specific power was added to the picture, a number would be called out. If no noise could be seen on the picture, then that number was to be written in the first column headed "Not Visible". If some noise could be seen, however, although it did not disturb the viewer unduly, then the number called should be written in the second column, headed "Just Visible". If there was sufficient noise present for the viewer to feel it would lower his appreciation of a programme being broadcast, then the number called should be put in the third column headed "Just Annoying", or finally, if the viewer felt there was a great deal of very disturbing noise he could write the number in the last column, headed "Very Annoying". It was emphasised that the numbers called would bear no logical relationship to the type and amount of noise being put into the picture. The viewers were allowed as much time as they desired to decide upon a category for each example given. Seven narrow bands of noise could be isolated from a spectrum of random noise. These were:

1. 0·0 – 0·30 Mc/s: mean value 0·15 Mc/s
2. 0·35 – 0·65 Mc/s: mean value 0·5 Mc/s
3. 0·85 – 1·15 Mc/s: mean value 1·0 Mc/s
4. 1·35 – 1·65 Mc/s: mean value 1·5 Mc/s
5. 1·85 – 2·15 Mc/s: mean value 2·0 Mc/s
6. 2·35 – 2·65 Mc/s: mean value 2·5 Mc/s
7. 2·70 – 3·00 Mc/s: mean value 2·85 Mc/s

The level of the noise in any given band could be adjusted by means of a variable attenuator in 1 dB steps. After a pilot run with a few subjects, it was found that 2 dB steps were usually desirable. The pilot run enabled an approximate idea to be obtained of the attenuation suitable for the output of each noise band which would make the noise "just visible" to most viewers. This knowledge was used to choose from 7 to 9 steps of attenuation of the output from each noise band. These steps were written down in random order with the aid of a table of random numbers and each attenuation was used twice. Thus between 14 and 18 numbers were written down for each noise band. The seven noise-band centre frequencies were themselves written

down in random order. Table 1 is part of the chart with which the experimenter was furnished.

Table 1

Part of Chart used by Experimenter

Centre Frequency of Noise Band	Prefix No.	Suffix No. 1	2	3	4	5	
1·0 Mc/s	1	25	27	21	29	27	. . . .
0·15 Mc/s	2	32	31	28	31	30	. . . .
2·85 Mc/s	3	22	16	14	14	20	. . . .
.	.	.	.	.	.	.	
.	.	.	.	.	.	.	
.	.	.	.	.	.	.	
.	.	.	.	.	.	.	
		dB of attenuation					

For example, number 2.3 refers to the 0·15 Mc/s noise band with 28 dB attenuation. With the aid of this chart it was possible for the various levels of the noise outputs to be shown to viewers in random order without giving any clue as to the amount of noise being added to the picture. The chart made it easy to read back, in dB attenuation of noise output, the numbers written on the papers filled in by each subject, an example of which is given in Table 2.

Table 2

Example of Paper filled in by a Viewer

Prefix No.	Not Visible	Just Visible	Just Annoying	Very Annoying
	Suffix No.			
1	4	1, 2, 5	3, etc.	
2	1, 2	4, 5	3, etc.	
3	1	5	2	3, 4, etc.
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.

Reading along the line in Table 2 denoted by the prefix No. 2, we see that for the suffix Nos. 1, 2, 4, 5 and 3, by referring to Table 1, a narrow band of noise centred around 0·15 Mc/s is not visible for 32 dB or 31 dB, is just visible for 31 dB and 30 dB and just annoying for 28 dB. This is purely an example of how the system is used, rather than an indication of the results actually obtained.

4. TREATMENT OF RESULTS.

The results of three batches of five viewers were added together and from their combined answers it was possible with each noise band to calculate the percentage of all occasions on which any particular amount of noise added to the picture was not visible, just visible, etc.

When the percentages had been calculated, the four columns were given weighting values. The first column "Not Visible", was given factor 0, the second column, "Just Visible", was given a factor of 1, the third column, "Just Annoying", received a factor of 2, and the last column "Very Annoying", a factor of 3. Each percentage value was multiplied by the appropriate factors and the total score obtained with each attenuation level was then calculated. If all the viewers decided that a particular value of noise in a given band produced an effect which was "very annoying" on each occasion that it was presented, that attenuation level would occur as 100% under the "Very Annoying" column, which has been weighted by the factor of 3, and the total score would thus become 300, the maximum possible score. If all the viewers placed the attenuation level under the heading "Just Visible", the score would be the 100; and under the heading "Just Annoying", the score would be 200. A noise attenuated to such a low level that no one ever saw it would score 0.

Figs. 2(a) and 2(b) show the scores derived in this manner plotted at each attenuation level investigated, for the seven noise-bands. Fig. 2(a) represents the results when the average viewing distance was approximately four times picture height and Fig. 2(b) when the average viewing distance was approximately eight times picture height. It is noteworthy that doubling the viewing distance (Fig. 2(a) to 2(b)) allows the noise power to be quadrupled for the same threshold to be maintained.

It is, in theory, possible for a score of 100 to be achieved at any one attenuation of noise-level, because all the readings might be placed under the heading "Just Visible". In practice, the same score will be achieved in numerous different ways. For example, half the readings may be placed under the heading "Not Visible", and half under the heading "Just Annoying", and the score will be (50% × 0 + 50% × 2). It is reasonable to assume, however, that the score 100 is a good indication that on the average a noise is "just visible" all the time, and from this assumption, if a score of 50 is attained, the noise is, on the average, "just visible" for half the occasions. The score 50 has been assumed to be representative of the borderline between "not visible" and "just visible" and at this score level, represented by a horizontal line in Fig. 2, the values of attenuation of output for each noise-band have been taken so as to draw a curve of threshold of visibility in terms of attenuation in dB for the seven noise-band mid-frequencies, Fig. 3. Similarly the score 200 has been assumed to indicate a complete certainty that the noise is "just annoying" and 100 has been taken as the threshold of annoyance. The values of attenuation of output for each noise-band at the score level 100 in Fig. 2 have been used to obtain the threshold of annoyance curves, which are shown in Fig. 3.

5. ANALYSIS OF RESULTS.

The four curves obtained, namely, threshold of visibility at viewing distances of four-times and eight-times picture height, and threshold of annoyance at

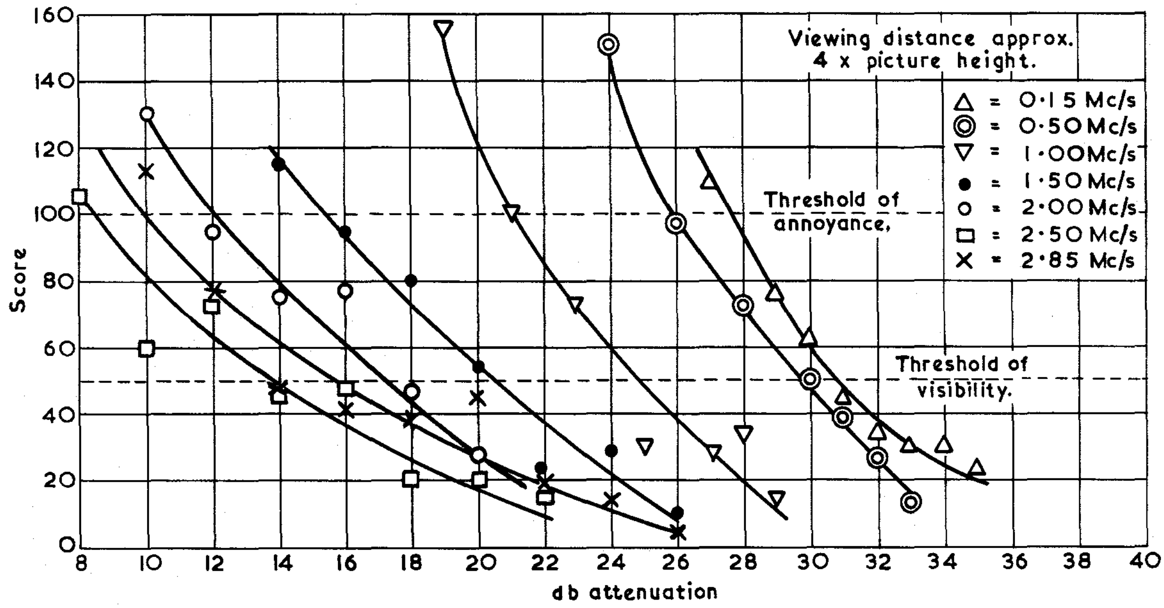

Fig. 2(a) - Relative visibility and annoyance of 7 different bands of noise superimposed on a still picture; plotted in terms of arbitrary scores

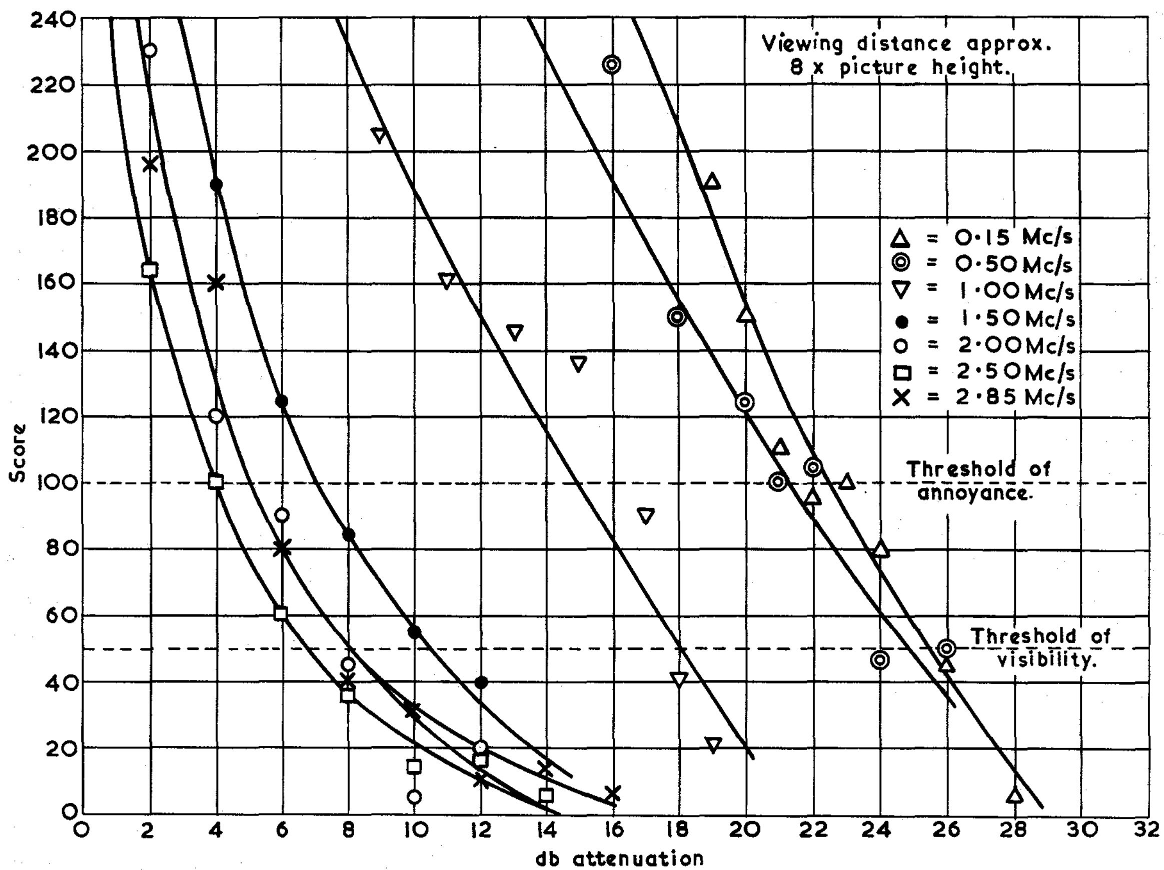

Fig. 2(b) - Relative visibility and annoyance of 7 different bands of noise superimposed on a still picture; plotted in terms of arbitrary scores

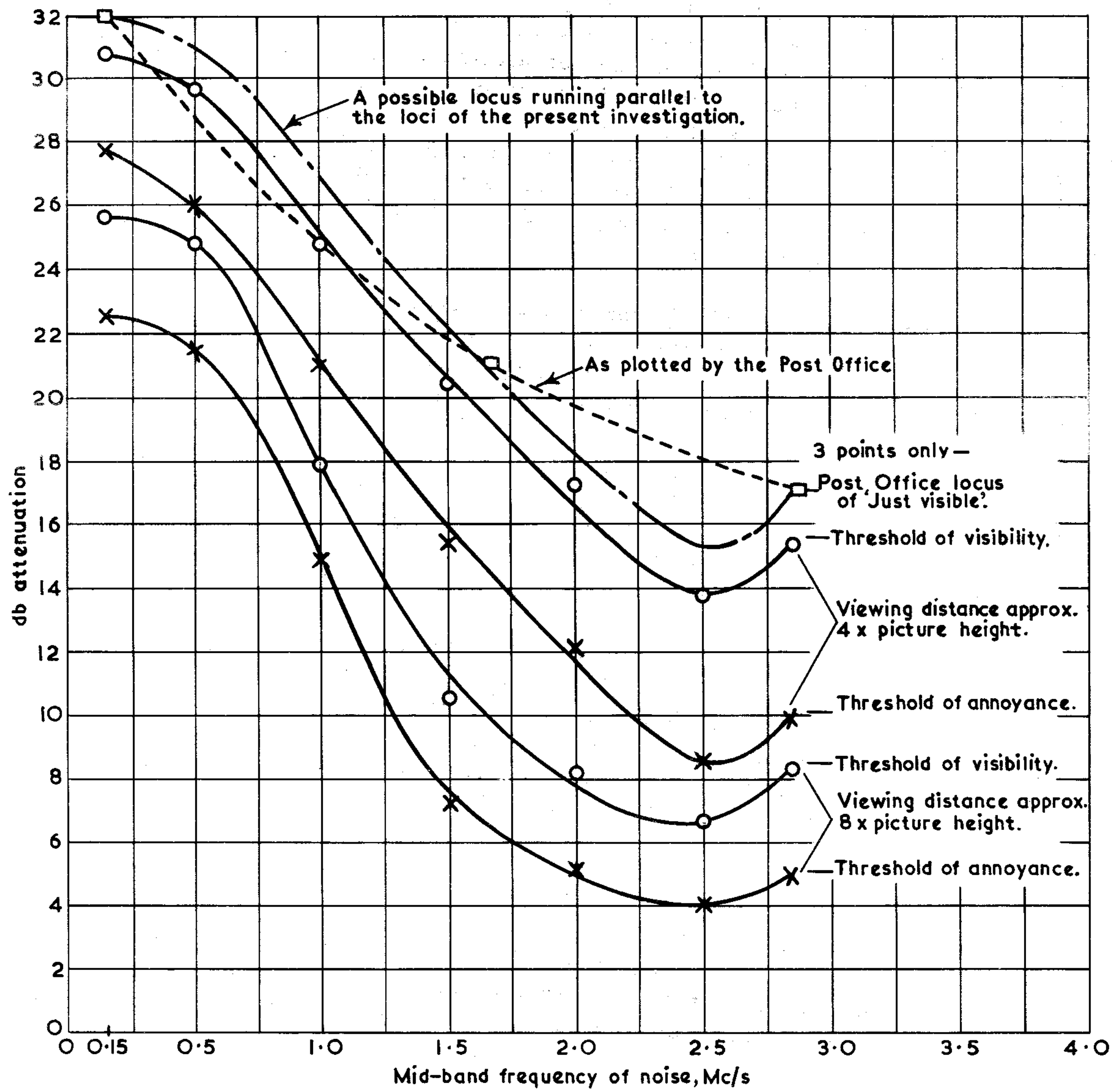

Fig. 3 - Thresholds of visibility and noise for 7 different bands of noise superimposed on a still picture

these same two viewing distances, are of similar shape and are very roughly parallel to each other. The Post Office Engineering Department carried out a similar investigation, using different methods of assessment, but using only three different noise bands. The three values they obtained are shown in Fig. 3 with the curve drawn through them by the Post Office investigators. Another curve has been sketched through these same three points more or less parallel to the four curves of the present investigation. Thus it can be said that the three isolated points obtained by the Post Office are not inconsistent with the present results. There is insufficient evidence to determine whether they do in fact lie on a similarly-shaped curve or on a curve of the type drawn by the Post Office, which is the simplest solution to the type of curve that may be expected when only three points are established.

Fig. 3 illustrates that noise tends to become less visible as the centre frequency of the band containing it moves up through the spectrum from 0·15 Mc/s to 2·85 Mc/s. There is, however, a minimum in each of the four curves, at 2·5 Mc/s. It may be argued that, as the centre frequency of a noise band becomes greater, the size of the units in the disturbance pattern it creates on the television screen becomes smaller and, therefore, less visible. This may account for the general trend of the four curves, but does not explain the minimum always occurring at 2·5 Mc/s, because the position of it would be expected to depend on viewing distance. As the two appear to be independent, it is not easy to account for this minimum, unless it is in some way associated with instrumentation.

The curves of threshold of annoyance run parallel to the curves of threshold of visibility and therefore indicate that annoyance is aroused when a noise pattern attains a fairly specific level of visibility above the threshold, of the order of 3 or 4 dB, and is more or less independent of the type of noise pattern.

This preliminary work thus establishes the relative visibility of narrow frequency bands of noise situated in the range from 0 to 3·0 Mc/s. It indicates the relationship between the "visibility" of noise and the "annoyance value" of noise. The results are not at variance with earlier work carried out by the Post Office Engineering Department.

The foregoing tests do not cover all the experiments necessary to obtain a complete answer to the problem of the dependence of noise visibility upon spectral distribution. In order to complete the investigation it will be necessary to carry out tests on a variety of shapes of noise spectra, and to examine further the cause of the anomalous minima at 2·5 Mc/s in the curves of Fig. 3. It might nevertheless be considered that sufficient information had been obtained to enable a suitable weighting network to be proposed.

The top curve in Fig. 3 approximates to the function $32 - 20 \log_{10}(1 + f^2)$ at least up to 2·5 Mc/s if f is in Mc/s. It will be observed that this is a function of $1/(1 + f^2)$. The latter expression is also the modulus of a transfer function constituted by the product of the transfer functions of two RC de-emphasis circuits. Thus, if noise were measured on a power or rms basis after passage through two de-emphasis circuits each having the time constant $RC = 0{\cdot}16\,\mu s$, (the weighting network being such that the impedance of the second circuit had no influence upon that of the first), it might be claimed that the visibility or annoyance of the noise would have been assessed with adequate precision.